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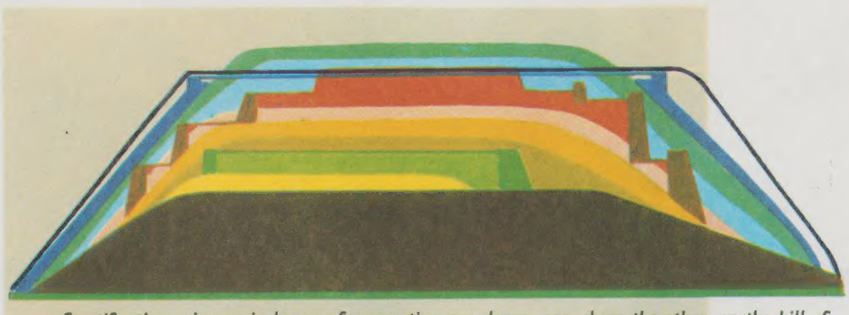
ARCHAEOLOGY (part one)

ARCHAEOLOGY is the study of how men lived in the past by examining the objects which they left behind them. There are a number of related sciences with which it is frequently confused. The most common is geology and the branch of it known as *palaeontology* – the study of fossils. Some *palaeontologists* are concerned with the fossil remains of early man, and there is no very clear line to show where their work ends and the archaeologists' begins. Many people confuse archaeology with *prehistory*, which is the time framework into which archaeologists fit the remains of the earliest people they study; in Britain this period is before the Roman invasion of A D 43. Not all archaeologists are interested in the prehistoric period; some are authorities on Roman remains, others on the Dark Ages or Norman times, and in recent years an interest has grown up in industrial archaeology – examining buildings constructed at the beginning of the Industrial Revolution.

The beginning of archaeology

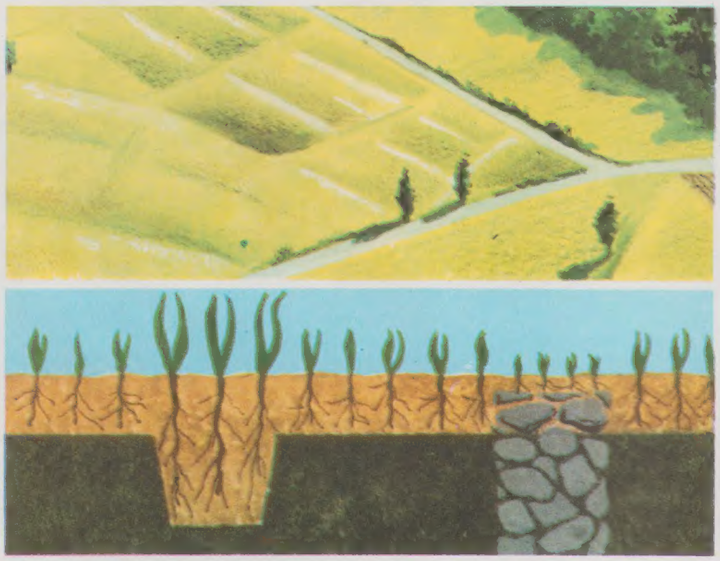
Today archaeology is a popular science; seldom a day goes by without mention of an excavation or discovery in a newspaper, or on radio or television. Once it was the exclusive pastime of country gentlemen. The first antiquaries were people like John Aubrey (1626–1697) and William Stukeley (1687–1765), who rode about the country in search of antiquities which they wrote about in their journals. In the second half of the 18th century barrow-digging became a popular pastime. These barrows or burial mounds needed little effort to dig and often contained rich grave-goods. Archaeology at that time was little more than treasure hunting.

It was Lieutenant-General Pitt-Rivers, at the end of the 19th century, who first introduced scientific method into the excavation of ancient sites. His digging techniques were so excellent that they have hardly changed since his death in 1900. On the other hand, great changes have been made in other branches of archaeological research. Some will be described later.



Stratification: nine main layers of occupation are shown, one above the other, on the hill of Troy. It is quite clear that the first, lowest layer is the earliest

Previous page: Two Egyptian mummies of the 7th century B C



An aerial picture (above) demonstrating how low ridges in a field are shown up by shadows cast by the evening sun. The ridges can hardly be seen at ground level; (below) wheat grows higher over a filled-in ditch, and is stunted over a buried wall

Broadly speaking, the archaeologist's work falls into two groups – field archaeology and excavation.

Field archaeology

The main concern of the field archaeologist is to go out into the countryside and examine the ancient earthworks which are still visible – burial mounds, camps, or simple banks and ditches. He will measure and map them, follow their course, and try to suggest reasons for their existence. He may search for new earthworks and is quite likely to discover a burial mound which has been ploughed almost flat, or to trace a length of Roman road or the ground plan of a destroyed church. In all this work the field archaeologist seldom puts a spade into the ground. His work is almost entirely based on observing surface features.

Excavation

To most people the word archaeology means excavation. This is something that can only be undertaken after years of specialised training and should never be attempted by an unskilled person. Excavation can be destructive. Once

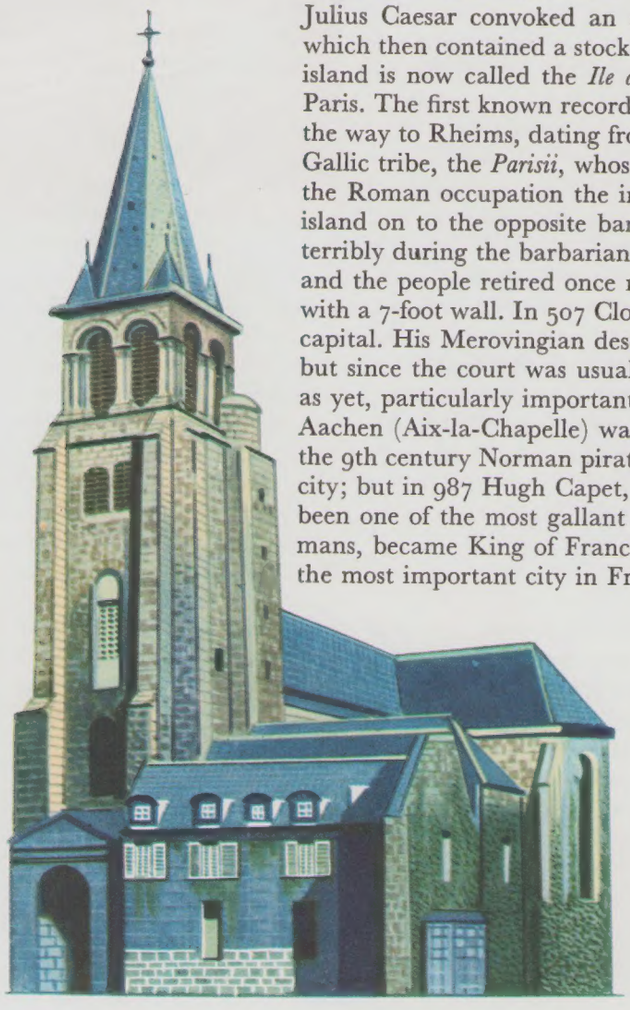
The Arc de Triomphe, the largest arch in the world, was begun by Napoleon in 1806 *to celebrate the victories of the French Army since the Revolution. It is based on the Arch of Titus in Rome. The French Unknown Warrior is buried under its vault*

PARIS (part one)

PARIS is nothing like the size of the world's largest cities – Tokyo, London, or New York – but for elegance, beauty, and vitality, France's capital can rank with any. And the long and glorious history of the French people is reflected in its buildings and monuments.

How Paris began

Paris is over 2,000 years old, but for half that time its limits went no further than those of a small island in the Seine. In 53 BC Julius Caesar convoked an assembly of the Gauls on this island, which then contained a stockaded settlement known as Lutetia. The island is now called the *Ile de la Cité*, and is the centre of modern Paris. The first known record of the name Paris is on a milestone on the way to Rheims, dating from 307. The name came from that of a Gallic tribe, the *Parisii*, whose stronghold the island was. Soon after the Roman occupation the inhabitants began to overflow from the island on to the opposite banks of the river, but the town suffered terribly during the barbarian invasions of the 4th and 5th centuries, and the people retired once more to their island and surrounded it with a 7-foot wall. In 507 Clovis, King of the Franks, made Paris his capital. His Merovingian descendants kept it as their headquarters, but since the court was usually touring the country Paris was not, as yet, particularly important; in fact, in the time of Charlemagne, Aachen (Aix-la-Chapelle) was the most important Frankish city. In the 9th century Norman pirates sailed up the Seine and ravaged the city; but in 987 Hugh Capet, a descendant of Count Odo, who had been one of the most gallant defenders of the city against the Normans, became King of France. It was only then that Paris became the most important city in France.



The church of Saint-Germain-des-Prés, the oldest church in Paris. Begun in the 11th century, its style is late Gothic with many Renaissance additions. For centuries this was the parish church of the kings of France. Its bells are the only ancient ones in Paris – all the others were melted down in the Revolution – and it is thought that they gave the signal for the massacre of Saint Bartholomew in 1572

Paris is divided into 20 arrondissements, *each with its town hall and mayor; these in turn are all divided into four* quartiers *with their own municipal councils*

A street in Montmartre, the village that was once the home of the Impressionists. In the background is the basilica of the Sacré-Coeur

A view of the Seine showing the Ile des Cygnes and the famous tree-lined embankment paths running under the bridges

THE MIDDLE AGES

By the end of the 11th century Paris had become a typical mediaeval town. The city guilds or livery companies developed the right bank as a mercantile centre; the *schools* of Paris, which were to grow into the University, made their home on the left bank. The population began to increase steadily, and Philip Augustus finally made Paris a self-contained unit by erecting a great rampart right round it, completed in 1209. The remains of these old walls can still be seen, although Paris has grown so much that they are now almost in its centre. It was about this time that the threefold division of Paris into the *town* – the bustling business and banking centre on the right bank; the *city* – the courts of the king and the bishop on the island; and the *University* – the future Latin quarter, on the left bank, grew up. These three districts later came to be administered as self-contained units with their own laws, and indeed they have retained their individuality right up to the present day.

The Black Death and the Hundred Years War brought building to a halt in Paris. Despite this, it was in the 14th century that the elegance of Parisian women was first praised, and in the 14th century too, in the years 1306, 1358, and 1382, the Parisians first rose against their rulers. So two of the characteristics with which Paris is traditionally associated, high fashion and political revolutions, are both 600 years old.

Paris did not recover from the Hundred Years War until the end of the 15th century. Its population was greatly reduced, its kings deserted it to live in the country, and brigandage became rife; there are even stories of wolves prowling in the streets. Nevertheless its first fine stone public buildings and churches were built at this time.

In the mid-16th century the Royal court moved from the island to the Palace of the *Louvre* on the right bank; many of the kings were great builders, so the right bank now developed rapidly.

RENAISSANCE AND REVOLUTION

Under Francis I and Henry II the Renaissance reached Paris. The aristocracy built great *hôtels* (mansions); the *Tuileries* gardens, designed by Catherine de Medici, became the meeting place of high society; the magnificent Louvre was constantly being embellished. Paris was now clearly the capital of one of the greatest states in Europe.

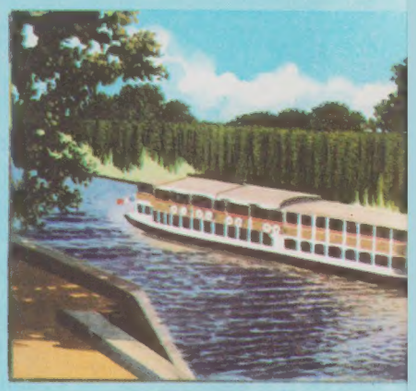
Henry IV repaired the damage done during the Wars of Religion (1562 to 1589), and introduced grand building schemes which were continued by Louis XIII and Richelieu. Louis XIV never forgave Paris for its part in the *Fronde* – civil wars which disturbed his early years as king. In 1663 he left Paris for good and went to live at his new palace at Versailles. Nevertheless, the 'Sun King' spent money lavishly on Paris as on everything else, and throughout the 17th and 18th centuries more and more fine buildings appeared in the city.

Over a hundred thousand people left Paris in the Revolution in 1789. But the Parisians who remained were at the forefront of the Revolution, and it was they who, in 1792, brought Louis XVI back from Versailles to guillotine him in their city. Napoleon wanted to make Paris a great imperial city – he planned to be the Caesar of a new Rome; but apart from completing the *Madeleine*, a temple to his glory, and ordering the *Arc de Triomphe* to be built, he carried out few of his plans.

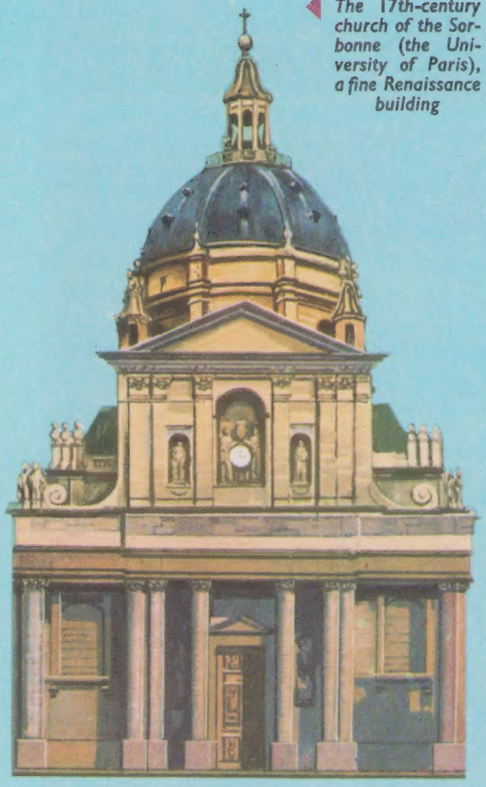
RESTORATION AND REPLANNING

With the restoration of the Bourbon monarchy in 1815 Paris began to grow more industrial. Gas lighting was introduced and in 1837 the city's first railway was constructed. But in 1848 Paris was still much as it had been in 1789 – a mediaeval town. The Paris of today was almost entirely created by Napoleon III with the help of Baron Georges Haussmann. The city was radically replanned; wide *boulevards* like those radiating from the *Etoile* were cut through the city; great squares were opened up; and spacious parks like the *Bois de Boulogne* were laid out. Disaster hit Paris during the Franco-Prussian War of 1870–1871, when the Parisians were first besieged by the German invaders and then rent by the Communards rising; there was fantastic loss of life. But afterwards the Third Republic continued Haussmann's work. The *Eiffel Tower* and *Sacre-Coeur* were built. Great international exhibitions were held, and Paris became a centre of art, amusement, fashion, and fine living. The First World War transformed Paris into a great industrial centre and sprawling suburbs sprang up around it. Despite the German occupation, the city was little affected by the Second World War.

A book-stall on the Seine embankment



A bateau mouche on the

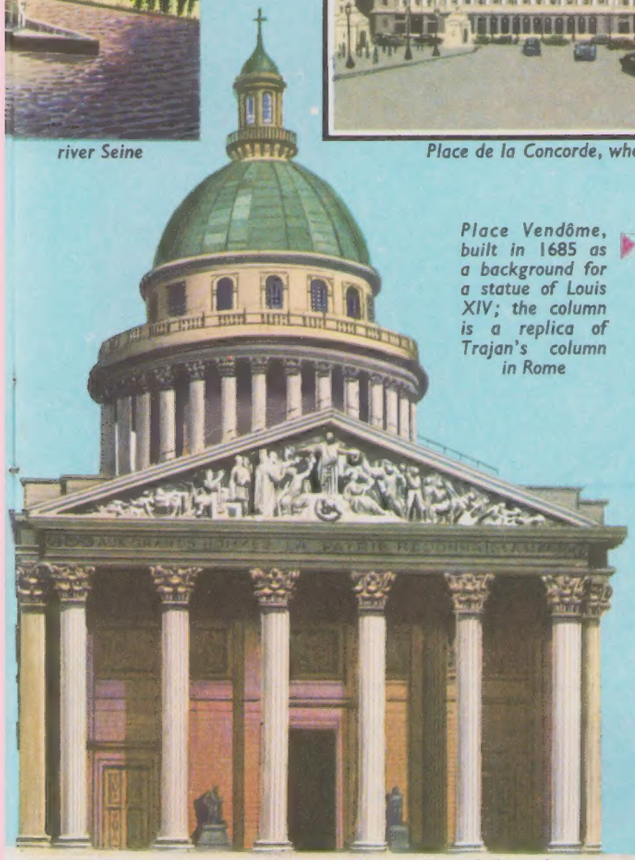


The 17th-century church of the Sorbonne (the University of Paris), a fine Renaissance building

The basilica of the Sacré-Coeur on Montmarte, begun in 1873 and finished 40 years later

river Seine

Place de la Concorde, where Louis XVI and Marie Antoinette were guillotined in 1792



The Pantheon, begun by Louis XV and the burial place of many great Frenchmen. Voltaire and Rousseau were buried here

Place Vendôme, built in 1685 as a background for a statue of Louis XIV; the column is a replica of Trajan's column in Rome

MONTMARTRE

Today the hill of Montmartre is one of the most famous parts of Paris. But until the 19th century it was a village well outside the boundaries of the city. The hill has been known as the *butte* ever since English archers used it for shooting butts after the Battle of Agincourt.

The Romans erected a temple to Mars on the summit; then in the 3rd century St Denis, the first Bishop of Paris, St Rusticus, and St Eleutheris were martyred on its slopes. So the Mount of Mars became the Mount of Martyrs. Legend has it that St Denis picked up his severed head, washed it in a spring, and walked on until he fell dead. A chapel was later built on the spot to commemorate him. Two other saints connected with Montmartre were Ignatius Loyola and Francis Xavier, who made the vows which founded the Society of Jesus (see page 801) on the hill.

Until the 18th century several windmills were in use on the hill, and its slopes were covered with woods and vineyards, but the farms of the flour millers and all the windmills except the *Moulin Rouge* and the rebuilt *Moulin de la Gallette* (cake) have now disappeared.

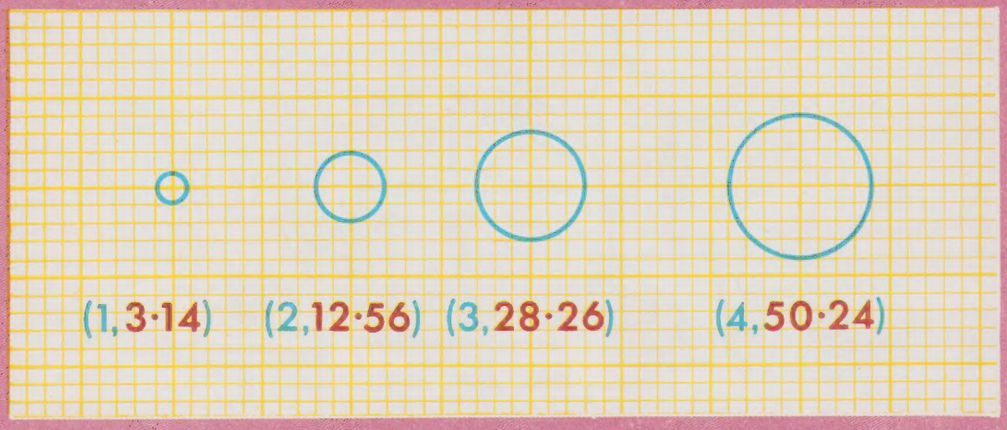
In the 17th and 18th centuries Montmartre was a notorious centre of crime and gambling, and an unsafe district for any law-abiding Parisian. But this changed in the 19th century. It was discovered by the artists, and became the village of the Impressionists. Manet, Monet, Van Gogh, Renoir, and Toulouse Lautrec, all lived there; and it was the setting of Puccini's opera *La Bohème*. There were music halls, dance halls, and even a circus. More recently Utrillo's paintings have made the streets of Montmartre famous throughout the world. Montmartre still has its studios and gay cafés but today they are visited by tourists rather than by anyone else, and the *Place du Tertre*, once the village green, is now the resort of foreigners.

The enormous dazzling white basilica of the Sacré-Coeur now dominates the hill. It was only begun in 1873, and was tremendously difficult to build; it rests on concrete pillars 400 feet deep. It was finished on the eve of the First World War.

GRAPHICAL COMPUTERS (PART TWO)

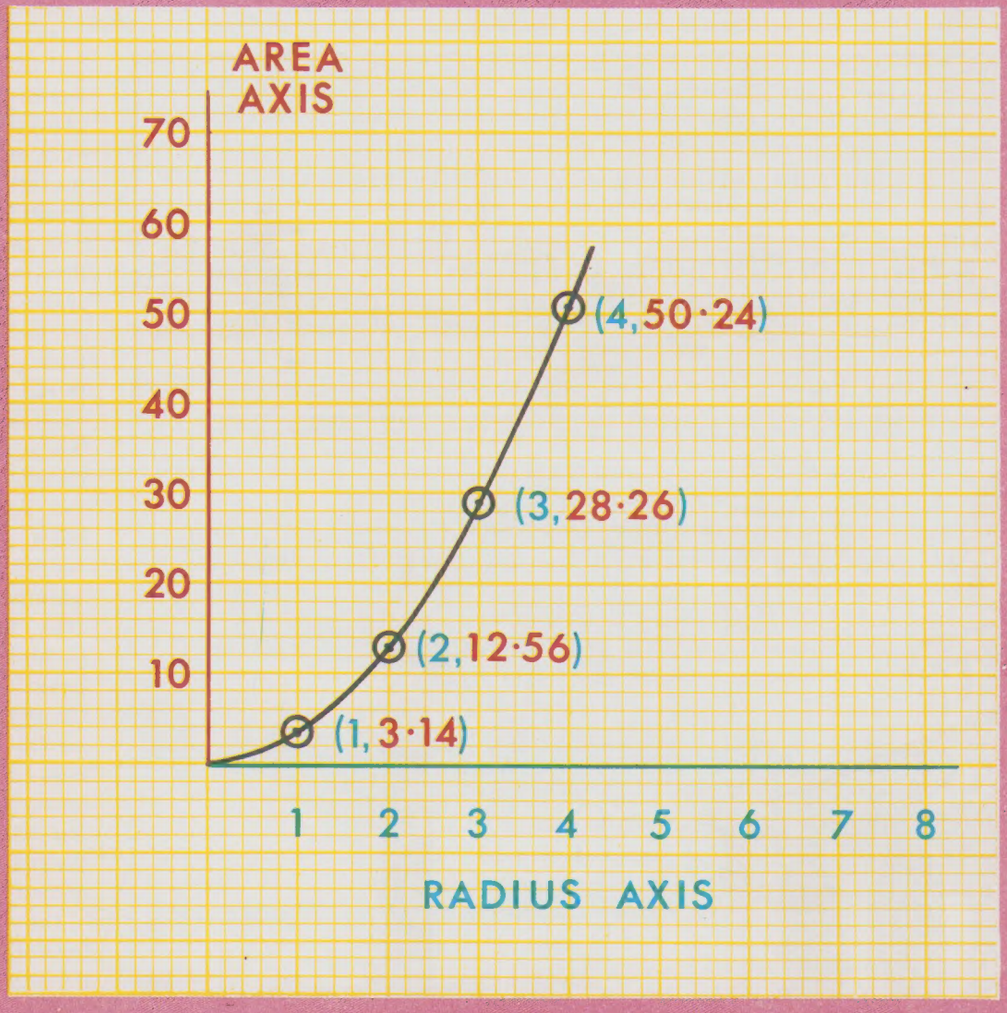
AREAS OF CIRCLES

On page 1992 we saw how the areas of circles depend upon their radii.



The number pairs associated with the circles are indicated below them; the first numbers give the radii and the second the areas.

Clearly circles of all sizes have similar number pairs, and if the related points are all plotted on graph paper they form a curve.



Can you find from the graph the area of a circle with radius 3·4 miles, and the radius of a circle whose area is 20 square yards?

Plot a graph showing the relationship between the circumference and radius of a circle, using a similar system.

LOGARITHMS TO BASE 2

Information about logarithms and antilogarithms (see page 2052) may be stored in number pairs:

(1, 2), (2, 4), (3, 8), (4, 16), (5, 32), (6, 64), (7, 128), and so on

the first number being the logarithm to base 2 of the second; $2=2^1$, $4=2^2$, $8=2^3$, and so on.

If the points associated with these number pairs are plotted on graph paper, as shown on the right, they will again form a distinct curved pattern.

There are number pairs (3·5, 11·3), (4·9, 30), and so on, associated with points on the curve. Are the first numbers the logarithms of the second in each case?

Let us try working, for example, $30 \div 11{\cdot}3$, assuming that this is so.

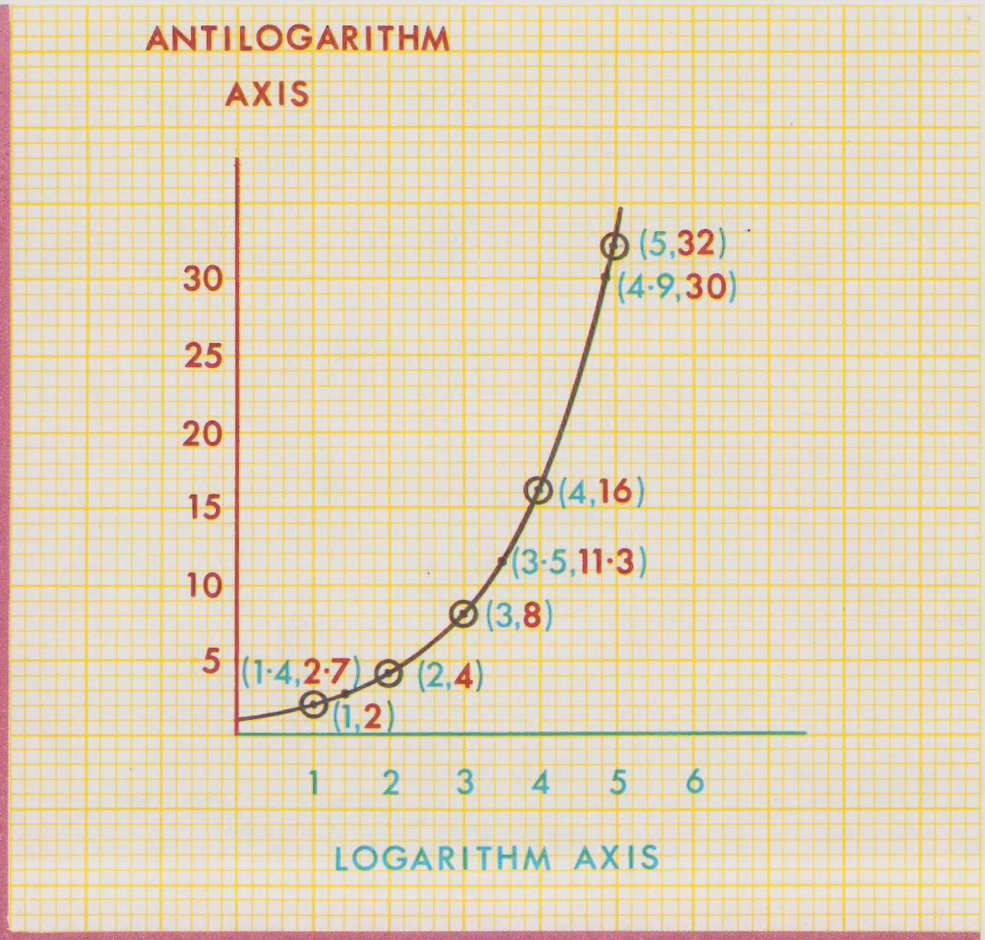
$30 \div 11{\cdot}3 = 2^{4{\cdot}9} \div 2^{3{\cdot}5}$

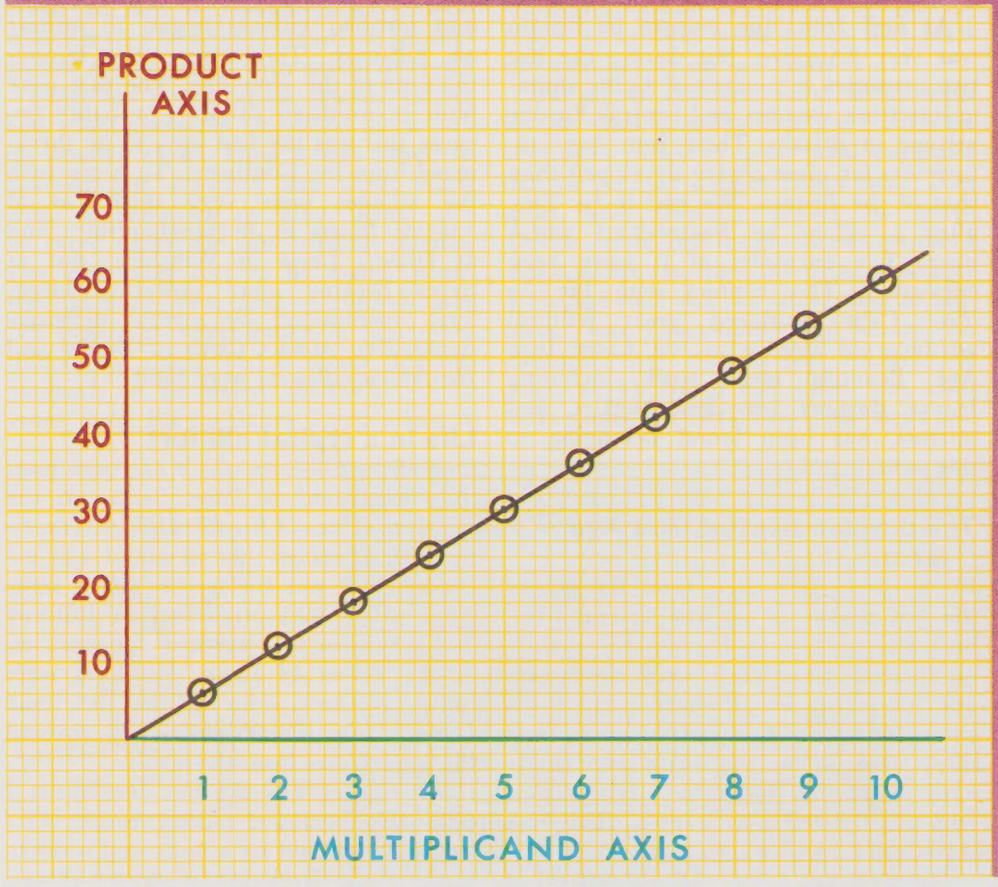
$= 2^{1{\cdot}4}$ (subtracting the indices)

$= 2{\cdot}7$ (from the graph)

which is near enough correct, so that it would seem reasonable to use our graph for finding any logarithm or antilogarithm to base 2.

Try some multiplication or division examples yourself.





MULTIPLICATION TABLES

We can summarise the 'six times table' in number-pair form:

(1, 6), (2, 12), (3, 18), (4, 24), (5, 30), (6, 36), (7, 42), (8, 48), (9, 54), (10, 60), and so on

the first number (*multiplicand*) being multiplied by 6 to give the second (*product*).

If points corresponding to every number pair are plotted on a graph they form a straight line.

Can you find from the graph on the left $6 \times 6{\cdot}65$ approximately?

Can you also find $50 \div 6$?

All the multiplication tables may be stored in graphs in this way and then used for calculation.

CONCLUSION

Whenever two quantities which vary continuously are related, graphs may be plotted and used as computational devices.

Try plotting graphs to show the relationship between Fahrenheit and Centigrade, miles and kilometres, pounds and grammes.

LIFE IN IRON AGE BRITAIN

THE Iron Age is the last prehistoric age. It came after the Bronze Age and began about 4,500 years ago, around the eastern shores of the Mediterranean, in Egypt and Asia Minor, where the people first discovered how to smelt iron from its ore. Their discovery spread slowly westwards across Europe and reached southern England in about 500 B C; here the Iron Age lasted until the Roman Conquest.

Late Iron Age bronze mirror from Old Warden, Bedfordshire. The surface was polished bronze

At first Iron Age culture in Britain was very primitive, but during the last two centuries B C waves of Celtic immigrants from western and central Europe arrived in Britain. Their Iron Age culture was far more highly developed than that of the Britons. We call it *La Tène*, after a village in Switzerland where many fine examples of it have been excavated. This contact with the *La Tène* Celts produced great cultural advances in Britain in the Later Iron Age. Beautiful metal work, including knives, daggers, brooches, buckles, and mirrors, has been found belonging to this period.

The development of Iron Age farms

In the early Iron Age, from the 5th to the 3rd centuries B C, the Britons lived in scattered farms. These were mainly on the chalk downlands, where the farmer and his family would share a large circular hut with their cattle, goats, and sheep. Around the hut was a large stockyard containing racks for drying corn, and pits in which to store it. This was surrounded by a stout wooden fence.

But a change came with the arrival of the Celtic immigrants; at first the Britons banded together to resist them. These small tribes united forming larger tribes, under powerful chieftains, and fortified villages began to appear on hill-tops. These were the famous hill-forts of the Iron Age. The first were built in southern Britain – probably because this was the first area to be threatened from the Continent. To begin with the villages were very small, as at *Ivinghoe Beacon* in Buckinghamshire and at *Oliver's Camp* in Wiltshire. But as tribes became more powerful, larger forts, surrounded by several defensive banks, like *Maiden Castle* in Dorset and *Herefordshire Beacon*, were built.

Life in a typical hill-fort

One of the hill-forts which has been most fully excavated is *Danes Camp*, on the southern slopes of Bredon Hill in Worcestershire. It seems that in about 150 B C Bredon Hill was the territory of a large tribe which had originated in Brittany and was then in control of the iron ore of the Forest of Dean. Hill-forts were built on three sides of the hill, and Danes Camp was the one which covered the approaches from the south.

We can see how this fort developed; it originally occupied about three acres and was enclosed by a bank and a ditch. Later it was divided in two by a wall and

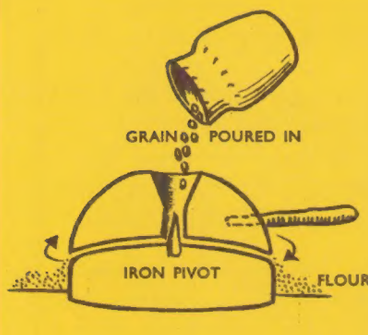
A reconstruction of the Danes Camp hill-fort in Worcestershire in about 100 *B C, showing the everyday life of the inhabitants*

a wooden palisade. A gateway led through the wall into the living-quarters. There were about a dozen circular huts, each about 20 feet in diameter, with stone walls about 2 feet high supporting timber-framed roofs covered with thatch or reeds.

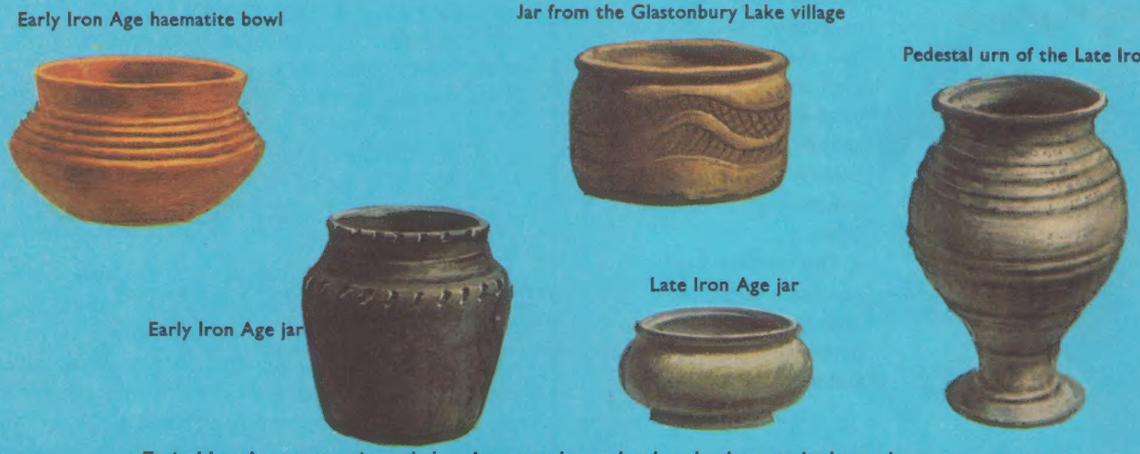
Corn was grown in the nearby valleys and when harvested was dried in the sun on wooden racks. Then it was stored in covered pits about 5 feet deep, lined with wicker-work or clay. After two or three years the pits became mouldy and new ones had to be made, whilst the old ones were used as rubbish pits. No buildings were found in the other half of the camp and it seems this was probably a protected paddock. As in many forts, life at Danes Camp seems to have come to an abrupt end. Danger must have threatened very suddenly, for the excavators found many signs of panic and wholesale evacuation, including the remains of mutton stews which had been dropped hastily on hut floors.

But not all hill-forts were on hill-tops. In the West Country forts were often on the lower slopes of hills; good examples can be seen at Milber Down near Torquay and Clovelly Dykes in north Devon. Some forts in central and southern England are also quite low-lying, and here Iron Age men did not always live in hill-forts. Near Glastonbury and Meare, for example, they lived in lake villages (see page 2273). Steep hill spurs and cliffs were sometimes cut off by high banks and ditches to form promontory forts, such as Gurnard's Head and Maen Castle in Cornwall. In southern Scotland some hill-forts had timbers running through the walls; these seem to have been deliberately burned, causing the stones near them to melt and fuse the walls into a solid *vitrified* (glassy) mass. In northern Scotland hill-forts were replaced by stone towers called *brochs*; in the western Highlands they were called *duns*.

The Iron Age in southern England ended soon after the Roman invasion of A D 43. In northern England it lasted at least another hundred years, while in parts of Scotland and Ireland it continued into the Dark Ages of the 5th and 6th centuries.



A rotary quern for grinding corn. The upper stone is revolved on the lower, and so crushes the grain


Early Iron Age haematite bowl
Jar from the Glastonbury Lake village
Pedestal urn of the Late Iron Age
Early Iron Age jar
Late Iron Age jar

Typical Iron Age pottery; the early Iron Age examples are hand-made, the rest wheel-turned

HERBAL REMEDIES

MINT sauce with roast lamb, thyme and parsley stuffing with veal; these are the uses of herbs which spring first to our minds today. But a hundred years ago people thought very differently. For our great-grandparents herbs were not merely plants with flavours which helped to make food interesting, but a gift from God to be employed in the treatment and prevention of illness.

For many thousands of years people relied almost solely on herbs in times of illness. Then, in the early years of this century, quite new kinds of drugs became available when chemists began to make medicinal compounds in their laboratories. These man-made drugs proved so effective that doctors came to use them more and more, and many of the old herbal remedies were abandoned.

To this day, however, there are still some people who prefer herbal medicines. They believe them to be a more natural way to health than the synthetic drugs made in laboratories. Experts who make herbal remedies are called *herbalists*, and their lore is written in books called *herbals*.

SOME MEDICINAL HERBS

PEPPERMINT (*Mentha piperita*)

Part used: the leaves

The peppermint plant, *Mentha piperita*, is much like the plant of the common garden mint, *Mentha viridis*. Peppermint is grown commercially for the oil that it yields. This oil is chiefly used as a flavouring agent in sweets, drinks, and unpleasant-tasting medicines.

The familiar smell and taste of peppermint are due to the presence of menthol and menthyl acetate.

LEOPARD'S BANE (*Arnica montana*)

Parts used: the flowers and the roots

Leopard's bane is a pleasant yellow-flowered plant which grows in woods and on hill pastures in many parts of Europe. The flowers and the roots are used to prepare a tincture which is used externally in the treatment of sprains. Unfortunately some people are sensitive to leopard's bane and react strongly to it. Perhaps the safest way to use this herb is to add a little of the tincture to a footbath.

Two 14th-century mortars in which dried herb preparations were ground to powder

VALERIAN (*Valeriana officinalis*)

Valerian often grows as high as 5 feet. It thrives best by the side of streams and in other places where there is plenty of moisture. The delicate pale pink and white flowers appear in June and last until August. Valerian is used as a sedative. Its taste is a particularly unpleasant one and for this reason it is usually taken in pills which can be swallowed quickly.

Parts used: the root and lower stem

WAYS OF PREPARING HERBAL REMEDIES

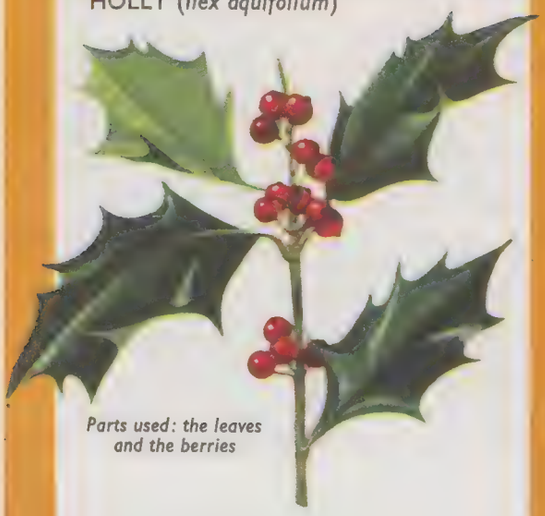
The number of plant species which are known or believed to possess medicinal properties is very large, probably about a thousand. It is usually the leaves of these plants which are chosen for the basis of herbal remedies, but sometimes the flowers, the fruit, or even the stem, the bark, or the roots are used.

In the days when herbal remedies were used almost exclusively, the task of finding the correct herbs and of making them into medicine was very much the work of the housewife, but nowadays it is not common for people to prepare herbal remedies for themselves. Many herbs are grown in commercial herb gardens, prepared in factories, and then sold in shops like any other commodity.

The manner in which herbal medicines are prepared varies a great deal. Some herbs are used in the form of dried leaves which are powdered, and compressed into *pills*. Others are taken as *infusions* prepared by pouring a pint of boiling water over an ounce of the herb in a jug. When it is cool the solids are filtered off and the clear liquid is ready for drinking. Herbal *ointments* are made by mixing powdered herb with hot lard, and *tinctures* by extracting dried herb by alcohol.

Old herbal remedies such as these are now seldom prescribed by doctors, but even today a few herbs are still of great medicinal importance, for they are the source of several most useful drugs. Among the products of these herbs are *morphia*, a pain-killing drug, which is obtained from poppies; *digitalis*, used in certain heart diseases, which comes from foxgloves; *atropine*, used in eyedrops, from deadly nightshade; and *quinine*, from the bark of the cinchona tree, which is used in treating malaria.

HOLLY (*Ilex aquifolium*)



Parts used: the leaves and the berries

Holly, one of the hardiest of all evergreens, is now used chiefly as a Christmas decoration. The berries have a purgative effect on humans, but as they are rather poisonous they cannot be recommended. Oddly enough, they seem quite harmless to birds.

SWEET VIOLETS (*Viola odorata*)

This pleasing little plant with heart-shaped leaves is grown for the perfume that it produces. Occasionally it is used for medicinal purposes in the form of syrup of violets, which is made by boiling the flowers in water and later sweetening it with sugar.

Syrup of violets has a mild laxative effect and is used as a medicine for children.

Parts used: the flowers and the leaves

CAMOMILE (*Anthemis nobilis*)

Part used: the flower head

Camomile tea is made from the flower heads of the camomile plant. It is prescribed as a nerve tonic and sedative.

In addition to its use as a herbal remedy camomile is sometimes grown as a lawn plant instead of grass. It forms a beautiful drought-resistant surface which is springy to walk upon.

DANDELION (*Taraxacum officinale*)

Parts used: the leaves and the root

The familiar yellow dandelion is found widely distributed in the northern hemisphere. The leaves are used in salads and a form of coffee is made from the roots.

Dandelion tea, made by pouring hot water on dried dandelion, is recommended in the treatment of biliousness.

BILBERRIES (*Vaccinium myrtillus*)

Parts used: the leaves and the fruit

This little plant is found in many parts of Britain. It is said that its fruit is useful in the treatment of dropsy, but the medicinal effects no doubt depend partly upon the gin or brandy in which the berries are steeped before use.

Parts used: the flowers and the leaves

VERVAIN (*Verbena officinalis*)

Herbal medicines made from the leaves and flowers of this plant are said to be good in nervous disorders.

It is claimed that merely to hang a sprig of the plant around the neck is enough to cure a headache.

HERBS FOR COOKING

Although herbs have lost much of their importance in medicine, they have certainly not become any less important in the kitchen, and no kitchen garden worthy of the name is without a patch of mint, a row of parsley, a sage bush, and a thyme plant. All these herbs, when properly used by the cook, give an additional flavour and zest to food.

Besides the well-known culinary herbs, there are many more which are both useful and delightful. Bay leaves improve sauces and stews, sprigs of borage enliven cold drinks, chopped chives lend interest to salads, and tarragon is often used to flavour vinegar.

WHAT IS A MAMMAL?

THE generally accepted brief definition of a mammal is 'a warm-blooded vertebrate animal that suckles its young'. This is good as far as it goes; no animals except mammals possess all these three characteristics together.

But mammals also have many other features, some peculiar to themselves, others typical of them but shared with one or more other groups of animals.

Exclusive characteristics

Ten features can be regarded as exclusive or peculiar to mammals: hair; mammary glands for the secretion of milk; a special arrangement of the cervical or neck vertebrae; sweat glands; the diaphragm; the larynx or voice-producing organ; the coiled cochlea of the inner ear and the three ossicles or small bones of the middle ear; the lips; the aorta arching over to the left; and the mandible or lower jaw formed of a single bone.

Typical but not exclusive

The following features are particularly well developed in mammals, but not exclusive to them:

Two pairs of limbs; these are usually developed for running, and sometimes for climbing, swimming, or flying. Each limb has five digits (fingers or toes) or less – never more. This feature is shared with birds, reptiles, and amphibians.

Viviparity; nearly all mammals bear their young alive – so do some reptiles and amphibians.

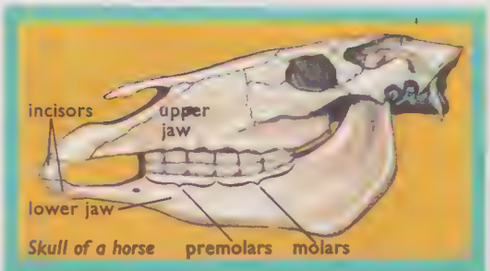
A constantly maintained high temperature; shared with birds.

The heart divided into four chambers; shared with birds and crocodillians.

Teeth; fish, amphibians, and reptiles also have teeth, but those of the mammals are much more highly developed and they are differently shaped according to their purpose or the type of food for which they are used.

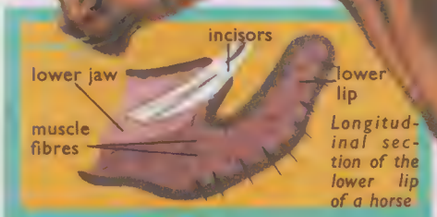
The brain of a mammal is convoluted (twisted in coils) and very highly developed.

We will now examine the horse as a typical mammal, and look at these different characteristics.

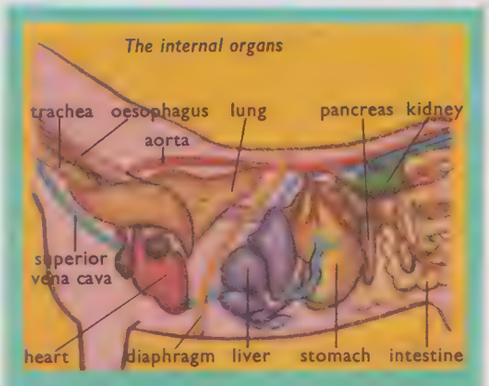


THE LOWER JAW – The mandible or lower jaw of mammals, alone among vertebrate animals, consists of a single bone. This is called the *dentary*.

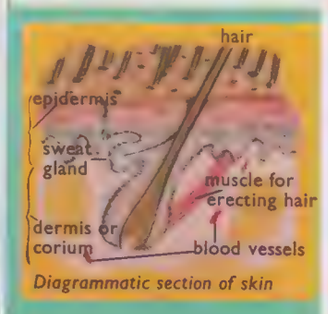
THE COCHLEA AND THE OSSICLES OF THE MIDDLE EAR – The cochlea is a spiral tube containing the hearing organ of the inner ear. The three ossicles (little bones) of the middle ear are called *malleus*, *incus*, and *stapes* (hammer, anvil, and stirrup) from their shapes. They connect the cochlea with the eardrum and are peculiar to mammals.



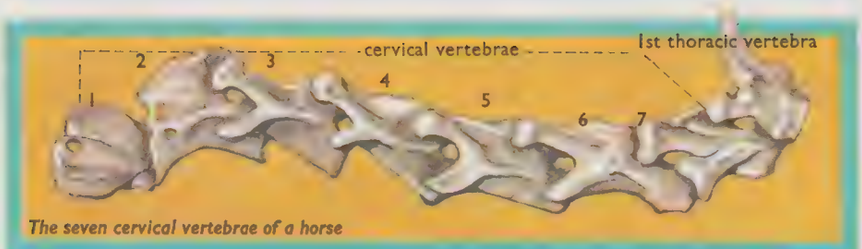
LIPS – The mouths of all mammals except the platypus (which has a beak) and its relative the echidna are bordered by lips.



THE DIAPHRAGM – The heart and lungs of mammals are separated from the abdominal organs (liver, stomach, intestine, and so on) by a sheet of muscular tissue called the diaphragm, forming separate thoracic (chest) and abdominal cavities. The action of the diaphragm draws breath into the lungs – a feature peculiar to mammals.



THE HAIR – All mammals have hair on their skin. Most of them have bodies completely covered by hair, but some tropical mammals, such as the elephant, have very little hair, while whales have only a few bristles around their mouths.

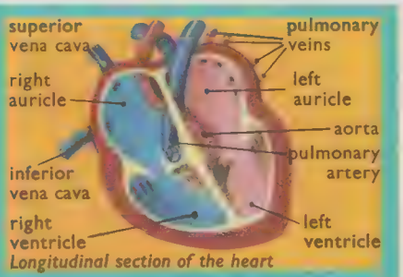


The seven cervical vertebrae of a horse

THE CERVICAL VERTEBRAE – These are the vertebrae of the neck. With very few exceptions all mammals have seven of them; this is true of the giraffe and also of the pygmy shrew whose neck is a quarter of an inch long. Exceptions are the dugong (Sirenia), with six neck vertebrae, and some sloths and anteaters. The first two cervical vertebrae are called the *atlas* and the *axis* and are modified to enable the skull to turn freely on the neck.

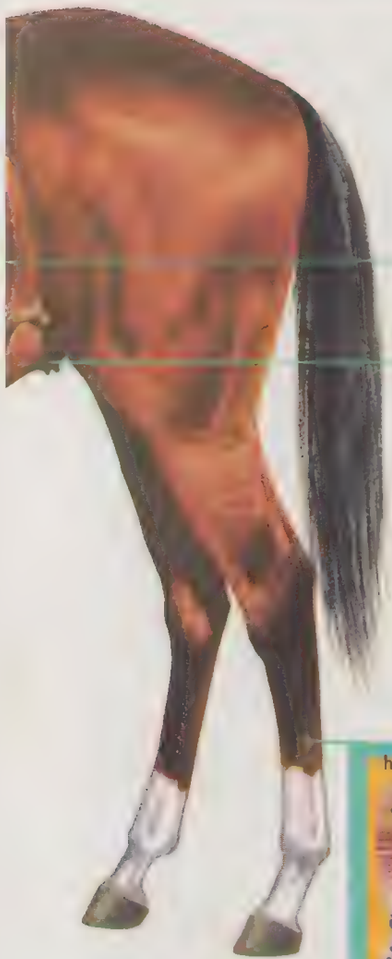
THE LARYNX – The larynx is the organ that produces the voice; it is worked by the passage of air from the lungs which makes the vocal cords vibrate. The voice of birds is produced by a similar organ called the *syrinx*.

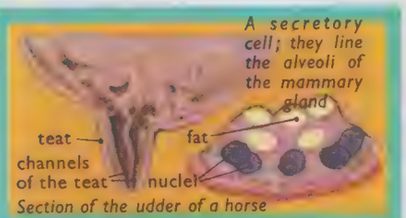
Larynx of a horse seen from the side



Longitudinal section of the heart

THE HEART – In mammals, as in birds and crocodiles, the heart is divided into four chambers, so that the blood from the veins and arteries is completely separated, resulting in double circulation (see page 218). The aorta of mammals turns over to the left, that of birds to the right.





Section of the udder of a horse

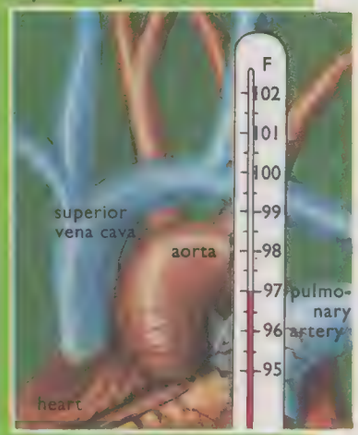
THE MAMMARY GLAND – All mammals, even those that live in the sea like whales, and the bats that fly, nourish their young with milk from a mammary gland called the breast or udder.

Section of the skin (greatly enlarged) showing hairs and a sweat gland

SWEAT GLANDS – These are found only in mammals. They pass liquid (sweat) out on to the skin; evaporation of this liquid cools the animal's body and so helps to regulate its temperature.

TWO PAIRS OF LIMBS – By origin the mammal is a quadruped, with two pairs of legs. The front pair may be modified to form flippers for swimming, as in the whales and dugongs; or to form wings as in bats; or arms and hands as in man and other primates. The hind limbs of whales and dugongs are rudimentary, having been reduced to small bones inside the body. The primitive number of digits (fingers and toes) is five but this may be reduced; in the horse only the third digit on each limb is fully developed.

TEMPERATURE – Both mammals and birds maintain their internal temperature at a constant level, usually much higher than that of their surroundings. They are able to do so because they have a warm coat of hair (or feathers) and very efficient blood circulation. The body temperature of mammals is generally about 95° to 100°F.



In mammals the body temperature is kept constant and rather high

Canine and molars of a carnivorous mammal (dog)

Many-pointed molars of an insectivorous mammal (mole)

Flattened molars of a herbivorous mammal (horse) adapted for grinding

TEETH – Fish, reptiles, and some amphibians all have teeth, which are simple and pointed and are used for seizing and holding the food. Mammals' teeth are differentiated in two ways from those of other groups. Firstly, a mammal has teeth of different kinds (incisors, canines, molars) for different purposes such as seizing, cutting, or chewing. Secondly, different kinds of mammals have teeth specially adapted for the food which they eat (see examples above).

THE BRAIN – All vertebrate animals have a brain, and many invertebrates such as insects have a kind of brain, even if it is only a small concentration of nervous ganglia. The brains of mammals, with the primates (monkeys, apes, and man) at their head, are most highly developed of all, and this has enabled them to gain their pre-eminent position in the world.

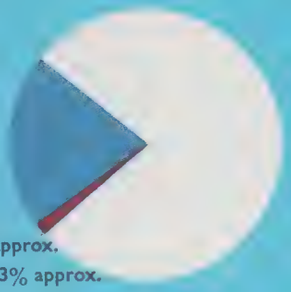
Brain of a horse seen from above

NITROGEN

JUST over three-quarters of the earth's atmosphere is composed of the colourless, odourless gas – nitrogen. Although we often think of gases as having very little weight, there is nevertheless about 60 pounds of nitrogen contained in the air in an average-sized living room. It has been estimated that there is over four million million tons of the gas in the whole atmosphere. Because it is an unreactive gas, and does not combine readily with other elements, there is very little nitrogen locked away in mineral deposits. Apart from a few isolated deposits of nitrate most of the world's nitrogen is in the form of the free gas.

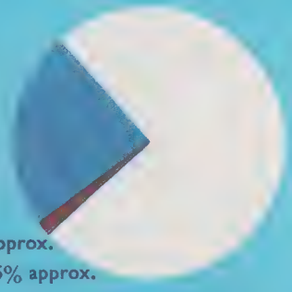
The existence of nitrogen as an element was not discovered until 1772 when the gas was isolated almost simultàneously by Scheele, Priestley, and Rutherford. They obtained it by removing the oxygen from an enclosed volume of air in combination with various oxidisable materials. The gas which remained, after the removal of any carbon dioxide, consisted of nitrogen (plus about one per cent of *inert gases*). With a very few exceptions, nothing will burn in pure nitrogen, and it will not support life. For this reason it was named *azote*, without life, by the French chemist Lavoisier, and it is still known in France by this name.

COMPOSITION OF THE AIR BY VOLUME



Nitrogen 78·09%
Oxygen 20·93%
Inert gases 0·95% approx.
Carbon dioxide 0·03% approx.

COMPOSITION OF THE AIR BY WEIGHT



Nitrogen 75·54%
Oxygen 23·14%
Inert gases 1·27% approx.
Carbon dioxide 0·05% approx.

THE NITROGEN CYCLE

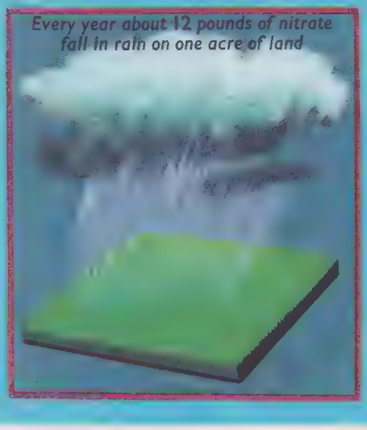
Although nitrogen was originally called the gas without life, it is an essential constituent of all living things. Proteins contain about 16 per cent nitrogen which originated in the air. We have already seen (see page 2080) that nitrogen is one of the essential mineral nutrients for plant life. But plants cannot use the nitrogen in the air directly; they can only absorb it when it is present in the form of nitrate (NO^{3-}). Nitrate is formed in the air by the combination of oxygen and nitrogen under the intense heat of a lightning flash; the soil receives some in rain water but too little to support abundant plant growth. Most of the nitrate in the soil is formed from the atmospheric nitrogen by *nitrogen-fixing bacteria*. The two main types of micro-organism which 'fix' nitrogen are the *rhizobium*, which live in the root nodules of leguminous plants like peas and clover, and the *azotobacter*, which live free in the soil. The way in which these organisms convert nitrogen to nitrate is not properly understood, but without them most plant life would be impossible. The protein in our bodies comes by way of the nitrogen-fixing bacteria (which take nitrogen from the air), plants, and the meat of animals which feed on them.

100 *square yards of the earth's surface contain about 100 pounds of combined nitrogen. The air above contains 700 tons of the gas.*

USES OF NITROGEN

Enormous quantities of nitrogen are used in the manufacture of fertilisers (see page 2080). It is also used in the manufacture of ammonia and nitric acid, both very important industrial chemicals. Ammonia is used in the process of dyeing and making drugs, and nitric acid is essential for making many explosives as well as fertilisers.

Small quantities of nitrogen are used to fill some types of electric-light bulb, and sometimes petrol and other inflammable liquids are stored with nitrogen to reduce fire risk.



Every year about 12 pounds of nitrate fall in rain on one acre of land

MANUFACTURE AND PROPERTIES

Pure nitrogen cannot be obtained from 'gaseous air', but by utilising the different boiling points of nitrogen, oxygen, and the inert gases pure nitrogen can be obtained by the *fractional distillation* of liquid air. All the industrially used nitrogen is obtained by this method. In the laboratory nitrogen can be obtained by heating a solution of ammonium nitrite.

Nitrogen forms three compounds with hydrogen. Ammonia (NH_3), hydrazine ($H_2N–NH_2$), and the highly explosive hydrazoic acid (HN_3). With oxygen, five or perhaps six different oxides are formed. Nitrous oxide (N_2O), or laughing gas, is a colourless gas used as an anaesthetic; nitric oxide (NO) is also a colourless gas. Dinitrogen trioxide (N_2O_3) exists at low temperatures as a blue liquid or solid. Nitrogen dioxide (NO_2) with its polymer dinitrogen tetroxide (N_2O_4) is a red gas which dissolves in water to give a mixture of nitrous and nitric acids. Dinitrogen pentoxide (N_2O_5) is a liquid which reacts with water to form nitric acid. A sixth oxide of nitrogen (N_3O_4) is also said to exist.

THE PHYSICAL PROPERTIES

Symbol: N.
Atomic number: 7.
Atomic weight: 14·008.
Density: 1·25 g/l at 0°C and 760 mm. pressure.
Melting point: −209·9°C.
Boiling point: −195·8°C.
Nitrogen is almost insoluble in water, only 2·33 c.c. dissolve in 100 ml. of water at 0°C.

Two stable isotopes occur in nature with atomic weights of 14 and 15.

Four great Renaissance figures, the painter Masaccio, the sculptor Jacopo de la Quercia, the architect Brunelleschi, and the sculptor Donatello, exchanging ideas on their art

THE RENAISSANCE

IF you could be transported back to any century between the 4th and the 14th you would feel completely out of place. People's ideas and the reasons for their actions would have seemed very strange to you. But if you could be carried back to the 15th and 16th centuries you might soon feel at home. For in these centuries the mediaeval world gave way to the modern; and present ideas about art, literature, and politics were born. This age was called the Renaissance. It got its name because it was, in fact, a rebirth – a rebirth of the ideas of Ancient Greece and Rome. It was in the age of the Renaissance that Europe again reached the standard of civilisation of classical times.

But the real driving force behind the Renaissance was the exaltation of the human being and 'humanism'. For instance, what distinguished Renaissance painters like Leonardo da Vinci, Raphael, and Botticelli from their mediaeval predecessors was the sheer accuracy with which they depicted the human form as something beautiful and perfect in itself. Not only did the Renaissance exalt man's appearance – it also exalted his achievements, which began to attain a new meaning apart from whether or not they glorified God. Although many Renaissance men like Michelangelo believed that man's great works did glorify God, this concentration on human accomplishments tended to raise man at the expense of God and give the Renaissance a secular (worldly) character.

The Renaissance, then, meant the exaltation of man and his works, including art, science, literature, architecture, sculpture, and politics. In all these fields the Renaissance was a time of such rapid advance that future students were sometimes deceived into thinking certain things actually began during it, when, in fact, what occurred was a phenomenal acceleration of tendencies many of which had been developing for centuries.

One effect of the developing idea that human beings guided their own destinies instead of being the unhappy tools of fate was that princes became much more concerned with their personal power and glory; hence the typical 'Renaissance Princes' like Henry VIII of England, Francis I of France, and Lorenzo the Magnificent of Florence (see page 1220). They sought to enlarge and glorify a very human institution, the State, even if it meant conflict with the divine institution of the Church.

Because the Renaissance idealised man, men came to feel that Christianity made man's achievements in this world seem insignificant beside the promise of the next. So it was natural that the artists and scholars of the Renaissance should have looked to the pre-Christian age when man was 'properly' respected – the ancient world of Greece and Rome.

With the emergence of powerful and independent princes came the breakdown of authorities which had hitherto hindered their freedom. The two authorities to suffer most were the Papacy and the Holy Roman Empire. By the mid-16th century not only was the Pope politically powerless in Protestant countries, but the Catholic kings of France and Spain had virtually as much freedom in the government of their churches as had the king of England in the government of his. The once mighty Holy Roman Empire was now little more than a name for hundreds of independent states.

To sum up, the new awareness of the excellence of human achievements led to a revolution, not only in art but in a wider sphere where it caused the overthrow of ideas concerning God and man which had been accepted throughout the Middle Ages.

The magnificent marble statue of St George, *by Donatello* (1386–1466), *the greatest Florentine sculptor of the early Renaissance* (Bargello Museum, Florence)

Moses *by Michelangelo* (1475–1564); *this work was intended for part of a monument to Pope Julius II but is now in the church of S Pietro in Vincoli in Rome*

The birthplace of the Renaissance

The Renaissance began in Italy in the late 14th century, and reached its peak there just before Charles VIII's invasion from France in 1494. After this it began to spread northwards across the Alps; by the time of the Sack of Rome in 1527 France, Spain, and England had replaced Italy as centres of the Renaissance.

Why was Italy so particularly receptive to Renaissance ideas? First, Italy had no central secular authority; she was then a collection of city-states (see page 1900). These states were sometimes at war with each other but the battles were, on the whole, minor ones; at the end of the 15th century, the peak of the Renaissance, Lorenzo de Medici of Florence established a balance of power among the states which created a far freer atmosphere than any tight central control could have done. Artists and scholars wandered freely from one princely court to another.

Secondly, Italy was more economically advanced than the rest of Europe. Her lively commercial activities (see page 1086) produced the exciting atmosphere of growth and expansion which was necessary before intellectual and artistic enterprise could really flourish.

Thirdly, the Italians prided themselves on their descent from the Ancient Romans and their association with much of what the Renaissance stood for, and it was natural that classical culture should be most enthusiastically revived in Italy. Let us now look at different aspects of the Italian Renaissance.

Painting, sculpture, and architecture

It was in the artistic field that the Renaissance man's confidence in his own creative power was most apparent. This resulted in a glorious flowering of the arts that has seldom, if ever, been equalled. Painting, sculpture, and architecture were transformed. The rather uninventive and stylised mediaeval forms were discarded and a new and vigorous spirit emerged.

Perhaps the greatest change was in the status of the artist. The Middle Ages had regarded the artist as no more than a craftsman. His subject was dictated to him by his patron and more often than not his name was not even remembered. The Renaissance, however, is full of great names. The architects Brunelleschi (see page 1306) and Alberti, the sculptors Pisano, Donatello, Verrocchio, and Ghiberti, and the artists Cimabue, Giotto (see page 1004), Botticelli, and Leonardo da Vinci worked in and around Florence, the centre of the early Renaissance. In Rome, the centre of the high Renaissance, worked artists and sculptors like Raphael (see page 1994) and Michelangelo, and architects like Bramante and Bernini.

Never before had artists been so free to imprint their personalities on their designs; they began to choose their own subjects and it was recognised for the first time that an artist was different from other men, not on account of his skill, but of his 'genius'. Academies like Lorenzo de Medici's Platonic Academy were founded; generous patrons abounded, and schools grew up around the great masters. There was a constant interchange of ideas and accuracy became the ideal. Figures like Michelangelo's *David* and those in his Sistine chapel paintings were no longer clad in mediaeval drapery but nude.

One of the six Slaves *designed by Michelangelo for Pope Julius's monument. It is a work of extraordinary strength although unfinished* (Academy of Fine Arts, Florence)

Renaissance artists were fascinated by the achievements of Greece and Rome. The rediscovery of the works of the Roman architect Vitruvius stimulated discussion about proportion and perspective; pagan and human subjects sometimes replaced religious ones, as in Botticelli's *Primavera*, but the artists were not bound by classical examples. For the artistic Renaissance was spontaneous and original, and inspired by pure delight in loveliness and harmony, in the beauty of the world and the beauty of man.

Literature

Since the Renaissance was the rebirth of classical learning many Renaissance authors wrote Latin commentaries on classical authors. But typical Renaissance literature is in the *vernacular* – native spoken language. The literature of the early Middle Ages had been in mediaeval Latin; but gradually the Renaissance 'spirit' led to works in Italian, French, Spanish, English, and German. The earliest great works in Italian were the *Divine Comedy* by Dante (1265–1321; see page 716), the *Canzoniere* by Petrarch (1304–1374), and the *Decameron* by Boccaccio (1313–1375). *Orlando Furioso* by Ariosto (1474–1533) was typical of the Renaissance.

Science and discovery

The newly aroused curiosity in nature affected scientists as well as artists. Leonardo da Vinci (see pages 2007, 2024, 2042), the classic example of Renaissance versatility, not only studied the human form but investigated the working of natural forces. He was fascinated by how things worked and his notebooks are full of diagrams of water and wind; he even devised a scheme for damming and diverting Florence's river, the Arno, and designed the blueprint for an aeroplane.

Scientists were constantly speculating on the nature of the universe and the earth. The Polish astronomer Copernicus (1473–1543) proved that the sun was the centre of the solar system; while the calculations of men like Toscanelli (see page 496) reinstated the ancient belief that the earth was spherical; the Portuguese Vasco da Gama rounded the Cape of Good Hope and Christopher Columbus discovered the New World. The Renaissance had, literally, widened the horizons of the world.

Education

The classical education which was standard throughout most of Europe until comparatively recently began in the Renaissance. It originated in the desire to provide a proper system for the study of Greek and Roman literature. Mediaeval universities had no defined place for classical learning; but in the Renaissance the ancient faculty of Rhetoric was used for this purpose. In this faculty was studied every aspect of the ancient world. Sometimes whole schools like Vittorino da Feltre's at Mantua were devoted to classical learning. Renaissance curricula devoted almost as many hours to physical as to mental development; fencing, gymnastics, and riding were practised.

The invention of printing in about 1440 was one of the greatest advances in history. During the Renaissance it greatly speeded the spread of learning; the Aldus printing house in Venice was the most important one in Italy, and books, at first on the classics, and eventually on every possible subject, poured from its presses.

Political theory

The belief of Renaissance men that it was in man's power to govern his own destiny led them both to re-examine the past and to reconsider the nature of politics. They now believed that it was not only the hand of God that was guiding human destiny – it was also humans themselves. So Villani and Guicciardini re-examined the histories of the Italian states. Moreover, as man could guide the destiny of states, there must be rules that governed the success of those states. These Machiavelli set down in the *Prince* (see page 1136). In this he tried to show that politics was a science and if a ruler followed certain rules he would get certain results.

Scientific method

Before the Renaissance people took things for granted – in the Renaissance nothing was taken for granted. Scientists and thinkers would not accept anything unless it was proved by experiment, observation, and deduction, or self-evident by reason. This was the spirit of later scientists like Bacon, Galileo, and Newton (see page 784).

One of the many great technical achievements of the Renaissance: the erection of an Egyptian obelisk in front of St Peter's, Rome, in 1586. This obelisk, brought to Rome in the reign of Caligula, was re-erected under the supervision of the architect Fontana

WILLIAM WORDSWORTH

WORDSWORTH lived in an age of industrial and political revolutions and was himself the cause of a revolution in poetry. He was born on 7th April 1770 at Cockermouth in Cumberland. He went to school at Hawkshead, where he studied classics, but he was given a great deal of freedom to roam around the countryside. In his frequent rambles he gained his lasting love of nature.

In 1787 he went to Cambridge University. He was not a keen student and in fact gained a poor degree. He showed no enthusiasm for any particular career. At this period he was inspired by the ideals of the French Revolution which he saw at first hand when he visited France in 1791. In 1793, however, he was recalled to England when his country declared war on France. This, coupled with his dismay at the French 'Reign of Terror', made him very despondent.

Wordsworth had grown into a reserved but not a shy young man. He was both hardy and independent, with a straightforward manner of speech and a Cumberland twang in his accent. The critic Hazlitt gave the following description of him: 'There was a severe, worn pressure about his temples, a fire in his eye (as if he saw something in objects more than the outward appearance), an intense, high, narrow forehead, a Roman nose, cheeks furrowed by strong purpose and feeling, and a convulsive inclination to laughter about the mouth, a good deal at variance with the solemn, stately expression of the rest of his face.'

The Lyrical Ballads

In 1795 a small legacy helped Wordsworth to settle in rural Dorset with his favourite sister, Dorothy. Although he felt he was destined to be a poet there was something holding him back, but this was removed when he met Samuel Taylor Coleridge. In 1798 the two produced the *Lyrical Ballads*. The *Ballads* were a complete break with the stilted language and formal structure of the poetry which was then fashionable. Both the language and the subjects written about by Wordsworth were simple and unaffected. Coleridge's main contribution to these *Ballads* was the famous *Ancient Mariner*.

In the *Lyrical Ballads* Wordsworth shows himself to be a truly great poet. He proclaims that he finds in nature the inspiration not only for his poetry but also for his life. In *Tintern Abbey*, one of the greatest blank verse poems in the English language, he writes:

'For I have learned
To look on nature not as in the hour
Of thoughtless youth; but hearing oftentimes
The still, sad music of humanity . . .
A sense sublime
Of something far more deeply interfused,
Whose dwelling is the light of setting suns,
And the round ocean and the living air,
And the blue sky, and in the mind of man.'

Wordsworth believed that in communion with nature a man could grasp more about why he was on this earth than in hours of reading books. The truth came, he thought, not by trying to reach it by thinking, but by feeling. In the *Lyrical Ballads* he wrote:

'One impulse from a vernal wood
Will teach you more of man,
Of moral evil and of good,
Than all the sages can.'

There was considerable opposition to this revolutionary type of poetry, but Wordsworth was convinced that he was right, although many of his later poems contained more conventional 'poetic diction'. In 1797 Wordsworth had moved to Grasmere in the Lake District and there continued his writing. In 1805 he completed the first version of his great autobiographical poem *The Prelude* which was not published until after his death. In 1807 he published his *Collected Poems* which contained several sonnets, the *Ode to Duty*, and the great *Ode on the Intimation of Immortality*. In the latter poem he puts forward the idea that in the purity and innocence of a child can be seen some of the perfection of its Creator and evidence of a previous existence:

'Not in entire forgetfulness,
And not in utter nakedness,
But trailing clouds of glory do we come
From God, who is our home.'

1807 was the end of Wordsworth's great period of poetic activity.

His domestic life had been calm. In 1802 he married a childhood friend, Mary Hutchinson, and in 1813 he was given a government sinecure (easy job) as stamp distributor, which brought him a considerable income. In his later life he became very self-centred and conceited, possibly because of the devotion lavished upon him by his wife and sister. In 1843 he was made Poet Laureate, and in 1850 he died.

William Wordsworth surveys Tintern Abbey, the subject of one of his greatest poems

A great romantic poet

Wordsworth will be remembered as perhaps the greatest of the romantic poets of the early 19th century. His genius enabled him to express vividly his love of nature and his belief in the essential freedom and liberty of man. Above all, he will be remembered as a simple poet who could write as perfectly and as naturally as:

'It is the first mild day of March,
Each minute sweeter than before,
The redbreast sings from the tall larch
That stands beside our door.'

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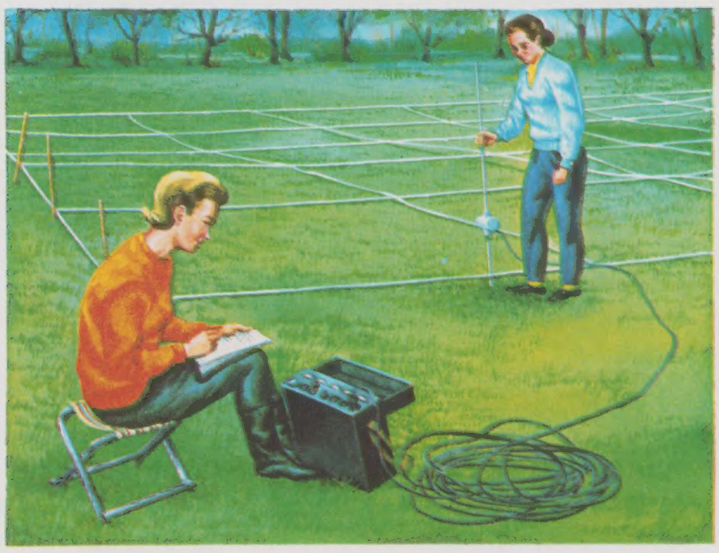
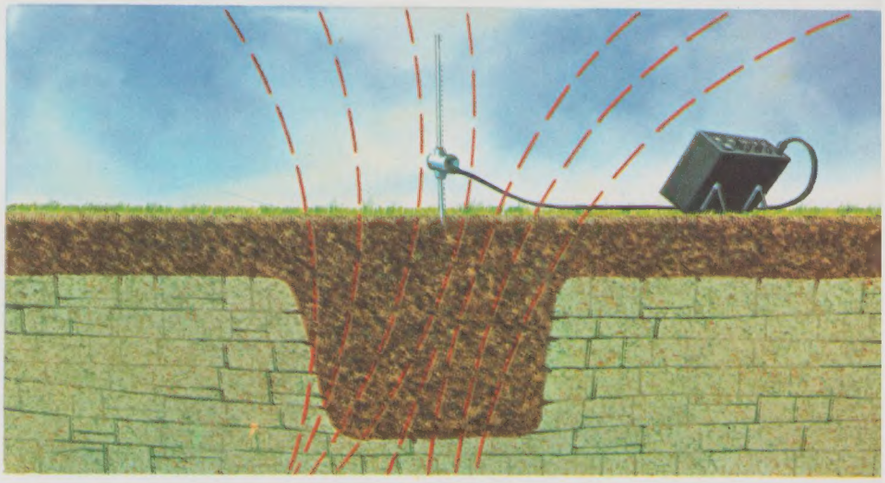
you have cleared the soil from an ancient site, you can never remedy it if you have missed something or made a mistake. The trained archaeologist is like a surgeon. He knows exactly where to cut his trenches in order to obtain the maximum information. Generally speaking, there are four kinds of excavations carried out in Britain. *Selective excavation* examines part of a site in order to find out the broad outline of its history. This is not always enough, and so sometimes *total excavation* is carried out in order to answer as many questions about the site as possible. Total excavation is expensive and is usually confined to small sites like burial mounds. Nowadays we often hear of *rescue excavations*, saving as much information as possible from a site that is about to be destroyed by building, quarrying, or the like. Many housing estates and schools have recently been built over such sites. Finally *re-excavation* can often be rewarding on sites that were dug in the 18th and 19th centuries. In those days a few holes were dug, leaving most of the site unexplored. No excavation is complete until the archaeologist in charge has published his report in a clear, simple style, giving descriptions, plans, and photographs of all that he has found, and what he believes it to have been. It is also his duty to place all the objects he has found in a public museum.

Discovering sites

One of the questions most frequently asked of archaeologists is: 'How do you know where to dig?' There can be several answers to this. Often the site is a clearly marked camp or barrow and only needs a trained eye to see it. Sometimes old maps or drawings show an earthwork which has since been destroyed. Such is the case with a small stone circle near Avebury (Wiltshire) called the Sanctuary, which was drawn by William Stukeley in 1723 and was destroyed the following year. Before excavation could begin (in 1930) the site had to be 'rediscovered', and in this the drawing was very helpful.

Two archaeologists operating a proton magnetometer





The proton magnetometer in use

In the last 25 years photography has played an important part in the discovery of countless sites. Sometimes buried ditches and low banks throw shadows in low evening sunlight which can be seen and photographed from an aeroplane. More often, wheat, or some other crop, growing over a filled-in ditch, grows higher and darker, due to the extra moisture stored in the ditch. Similarly low walls and floors below the field surface cause the wheat to become stunted due to lack of moisture. All these effects can be seen from the air and reveal the plans of all sorts of buried features (see diagram on the previous page).

The simplest method of finding the site on the ground is by *probing* – pushing a thin metal rod into the ground and feeling for buried walls and ditches. A more elaborate method is known as *resistivity surveying*, and is based on the ability of different kinds of soil to conduct different amounts of electricity. In the past eight years British scientists have developed a new method of detecting buried earthworks with a machine called a *proton magnetometer*. This device will save many hours of useless digging.

The proton magnetometer

Iron and steel are magnetic, and because of this a compass needle will indicate a false direction for magnetic north if used, for example, near iron railings. The railings *distort* the normal magnetism of the earth. Very, very slight distortion is also caused by archaeological ovens, hearths, furnaces, pits and ditches. This is because fire and cultivation have the rather surprising effect of increasing the weak magnetism of the small amount of iron oxide usually present in soil and clay. The distortion is far too small to be detected with a compass, but a *proton magnetometer* can find the exact position of buried ovens, pits, and so on, on an archaeological site even though there is not the slightest sign on the surface. The detector of the proton magnetometer (see diagram on the left) is merely a container of water with an electrical coil wound around it. Protons – the

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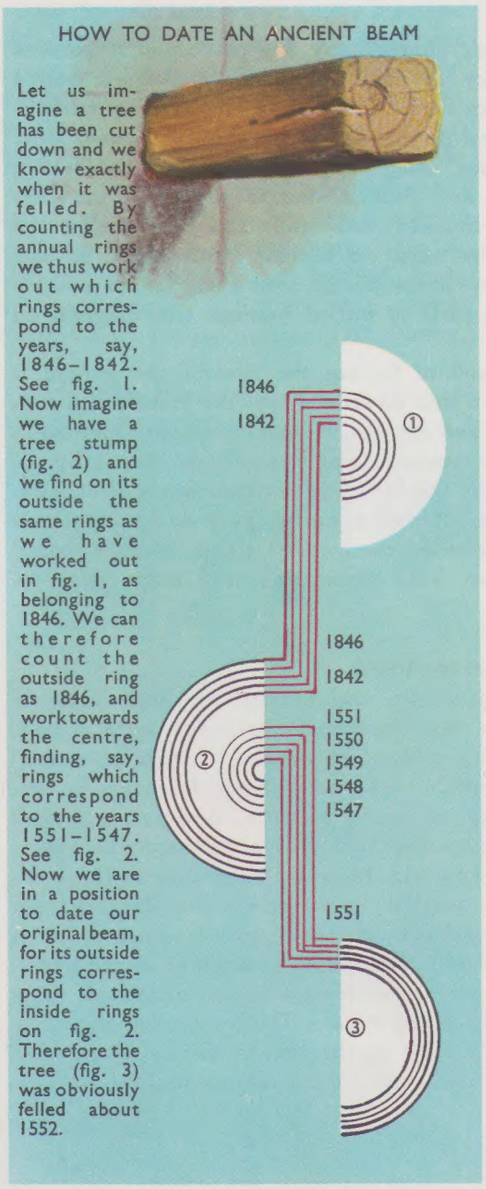
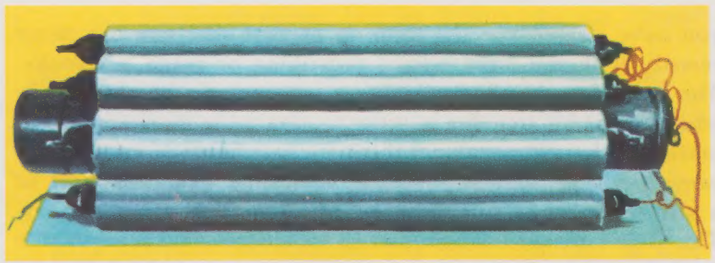
nuclei of the hydrogen atoms in the water – behave differently according to the magnetic strength in which they find themselves. Their behaviour is analysed by complex transistor circuits and the answer is simply presented on five meter dials. One operator moves the detector container, and the other one reads the dials; in this way the hidden pits of a prehistoric hill-fort can be pin-pointed rapidly and without wasteful trial-trenching.

How old is it?

In an excavation the answer to this question may be provided by *stratigraphy*. That is, the piling up of one layer of occupation upon another. In the Middle East, when one ancient town collapsed, another was built on top of it. By carefully digging off the towns from the top of the pile to the bottom, the archaeologist works back from the most recent to the earliest settlement. If the excavator knows the age of one of the towns, he can say that those below it are earlier, and those above it later (see illustration of Troy). If an archaeologist finds a ditch with Bronze Age pottery in it, covered over by a Roman road, he can be certain that the ditch was there first, and is accordingly older than the road.

Another method used to date objects from an excavation is called *typology*. Imagine arranging half a dozen pictures of aeroplanes in order without knowing their names or dates. You would be almost certain to place a Vickers Vimy bomber and an Avro Vulcan bomber at different ends of your series. A similar method is used in archaeology, but here a series of objects such as axes are arranged in a logical order, progressing from the simplest to the most complicated. If one of the objects can be dated, it is assumed that the ones before it in the series are earlier, and those after it later, though some things, instead of getting better, get worse.


HOW TO DATE AN ANCIENT BEAM
Let us imagine a tree has been cut down and we know exactly when it was felled. By counting the annual rings we thus work out which rings correspond to the years, say, 1846–1842. See fig. 1. Now imagine we have a tree stump (fig. 2) and we find on its outside the same rings as we have worked out in fig. 1, as belonging to 1846. We can therefore count the outside ring as 1846, and worktowards the centre, finding, say, rings which correspond to the years 1551–1547. See fig. 2. Now we are in a position to date our original beam, for its outside rings correspond to the inside rings on fig. 2. Therefore the tree (fig. 3) was obviously felled about 1552.
1846
1842
①
1846
1842
1551
1550
1549
1548
1547
②
1551
③



The counter used in radio-carbon dating; it is protected from modern cosmic rays by a steel screen 8 inches thick

Other sciences such as geology, botany, astronomy, and even physics, now help archaeologists to date their materials. *Dendrochronology* is a method of dating wood by counting the annual growth rings in trees. Wet summers produce thick rings and dry summers narrow ones; so a long period of wet or dry summers can be seen by examining the thickness of tree rings. It is possible to carry this method back by matching rings in a recently felled tree with those in an earlier tree. In this way beams in old houses or wrecked ships can be related to one another and accurately dated. The Americans have used this method to date Pueblo Indian dwelling sites which were built 1,900 years ago.

Ancient objects such as wood, bone, or grain can be dated by means of their radio-activity. This method is known as *radio-carbon dating*. All living things contain a very tiny amount of radio-active carbon of atomic weight 14 (C^{14}), which is known to decrease in amount by exactly half in 5,570 years (its half-life). Living organisms take in fresh carbon from the air and from their food, but when they die the amount of carbon in that organism starts to decrease. Since scientists know the half-life of carbon-14 they can find out how long it is since any object ceased to live. Some charcoal from one of the Aubrey Holes at Stonehenge, excavated in 1950, gave a carbon-14 date of 1848 B C.

How to become an archaeologist

Perhaps you would like to know how to become an archaeologist. You can begin by joining your local archaeological society, whose address you will find at your local museum. The best way to learn is by experience, and so you should try to visit any excavations in your neighbourhood. Some excavations take children over 12 years old as helpers. Details of 'digs' can be obtained from the Secretary of the Council for British Archaeology, 10, Bolton Gardens, London S.W.5. Remember, you should not try digging on your own until you have been properly trained. Many ancient sites are protected by law and you could get into serious trouble if you started to dig on them. When you leave school a university degree is almost essential if you wish to become a professional archaeologist, and again the Council for British Archaeology will be glad to advise you.